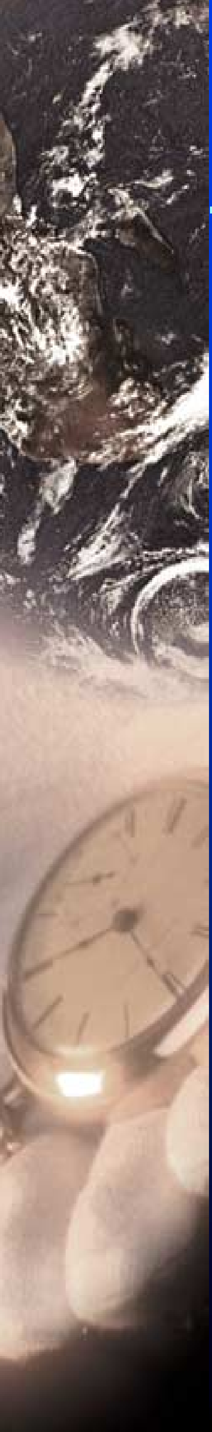

# Hybrid Vehicle Systems Optimization using ADVISOR and iSIGHT


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National Renewable Energy Laboratory

Golden, Colorado



iSIGHT User's Conference

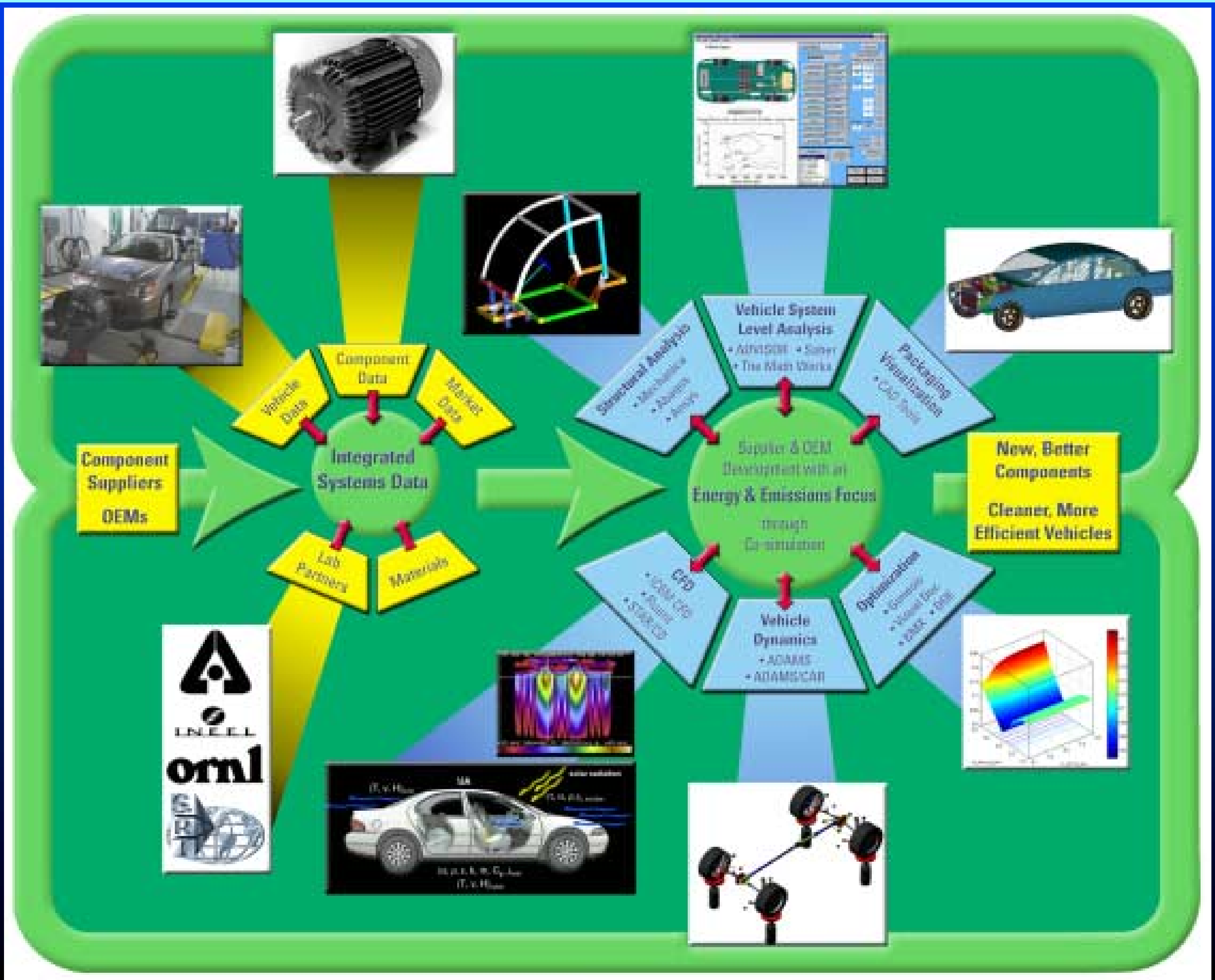
Southfield, Michigan

May 16-17, 2001

# Outline

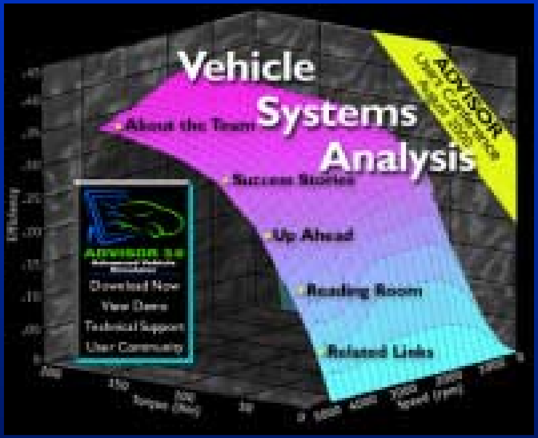
- Digital Functional Vehicle Vision
- ADVISOR Overview
- iSIGHT-ADVISOR Application
- Results Discussion
- Conclusions and Future Plans

# Overall Vision: Digital Functional Vehicle



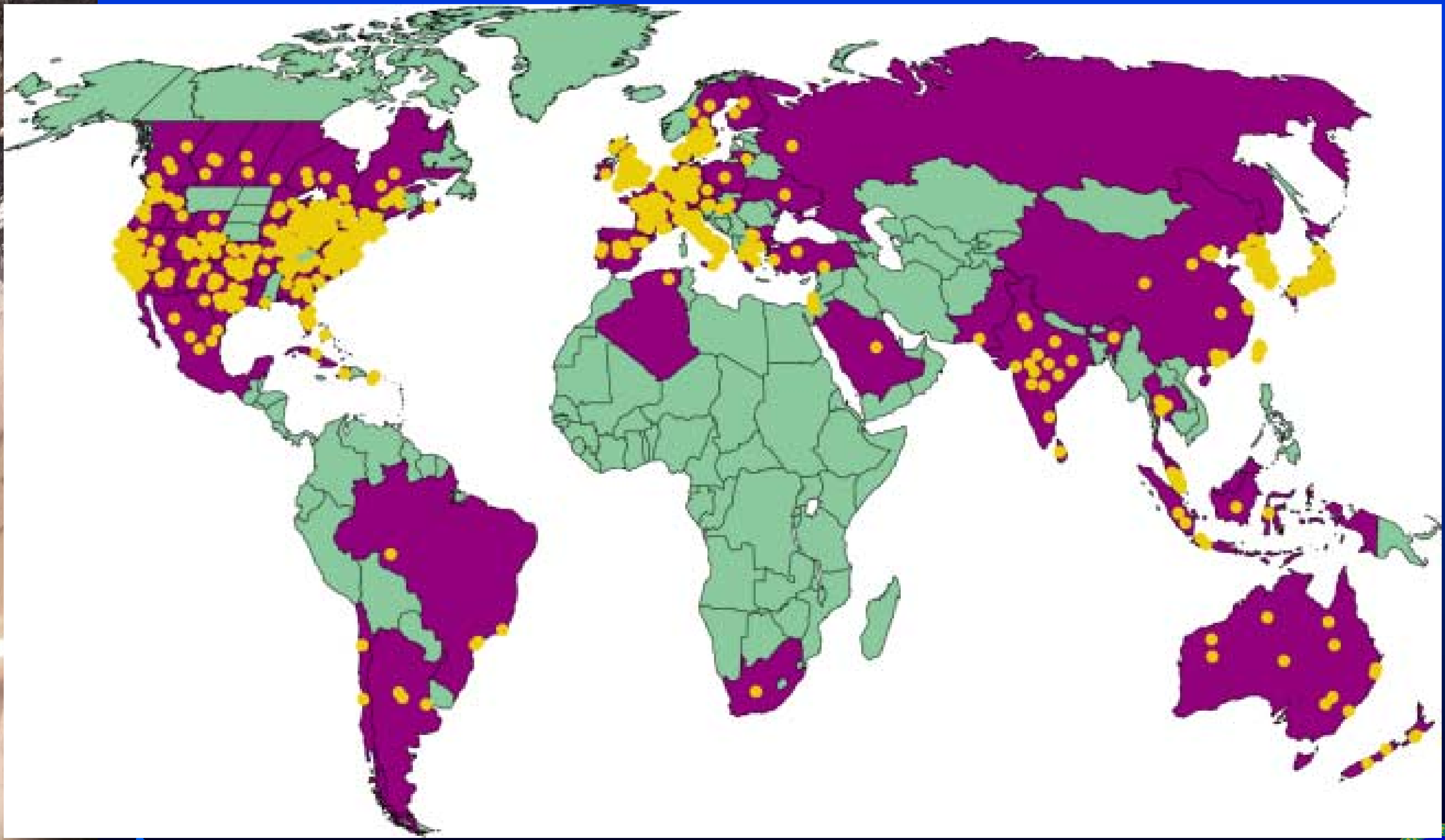
# Background on ADVISOR

- ADVISOR = ADvanced VehIcle SimulatOR
  - simulates conventional, electric, or hybrid vehicles (series, parallel, or fuel cell)
- ADVISOR was created in 1994 to support DOE Hybrid Program at NREL
- Released on vehicle systems analysis web site in September, 1998

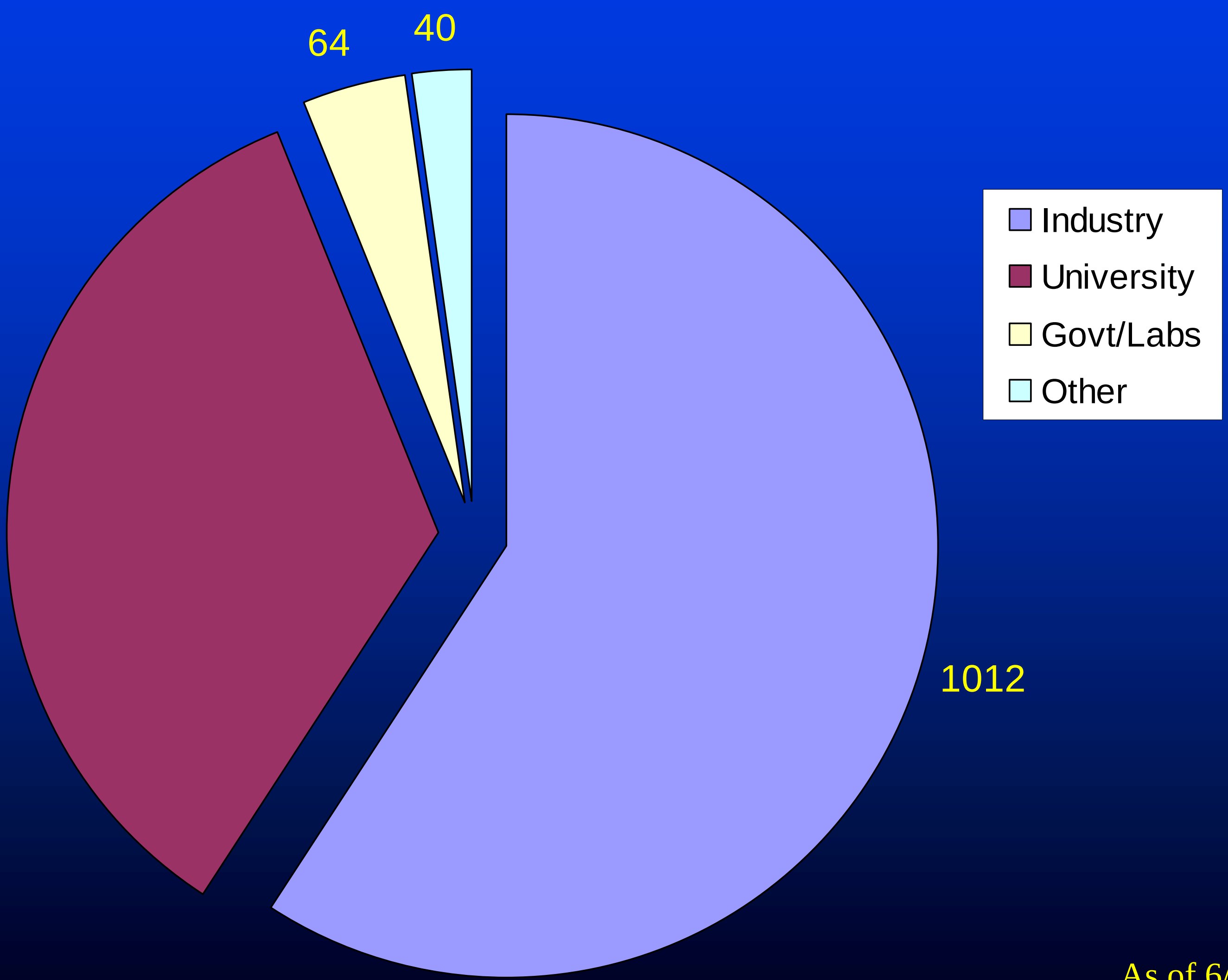



- Downloaded by over 3400 people around world
- Users help provide component data and validation, feedback for future development

# ADVISOR Being Used Globally
# April 2001: >3400 users

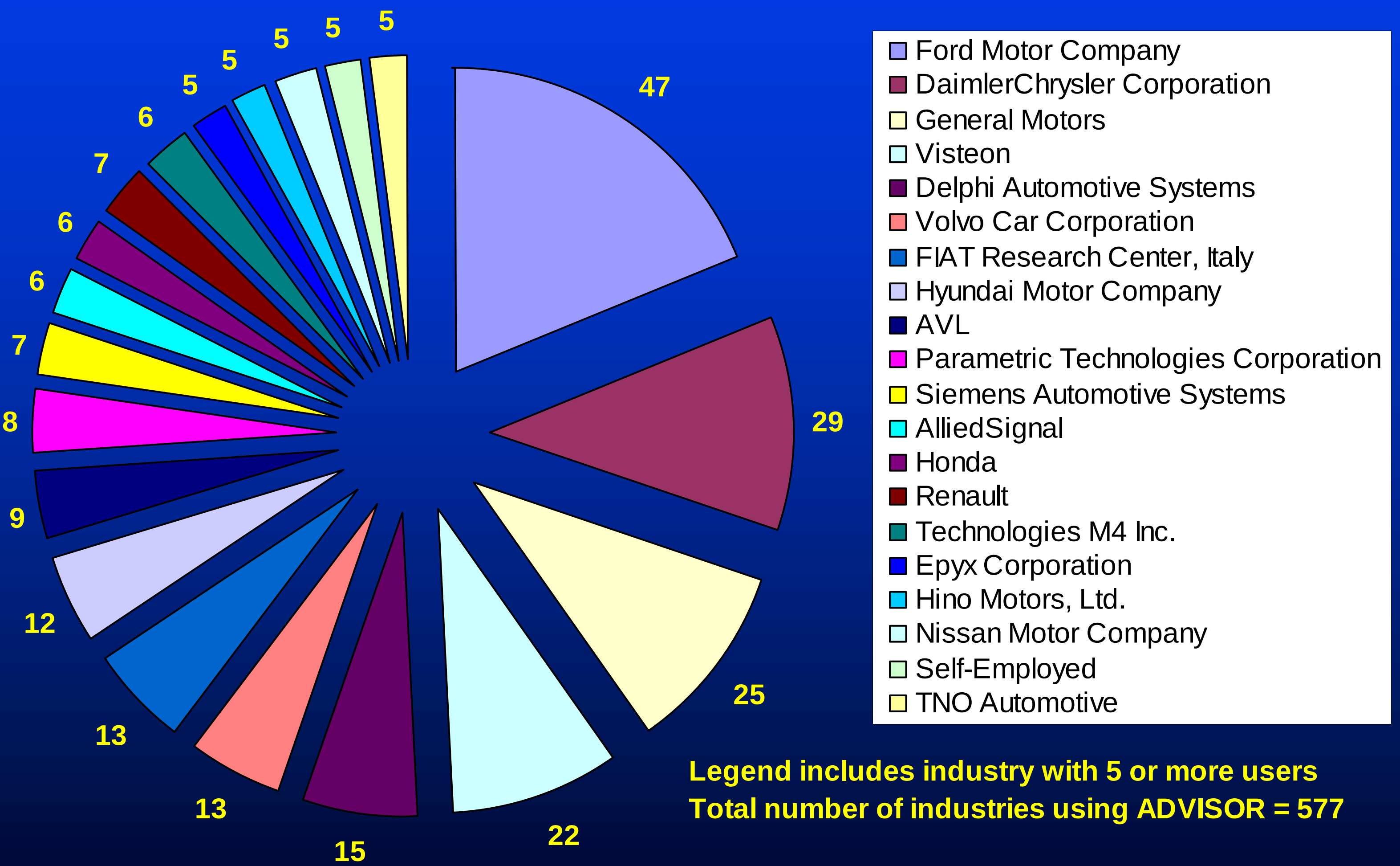


# ADVISOR Downloads by Type of Organization




As of 6/7/00

# ADVISOR Downloads by Industry

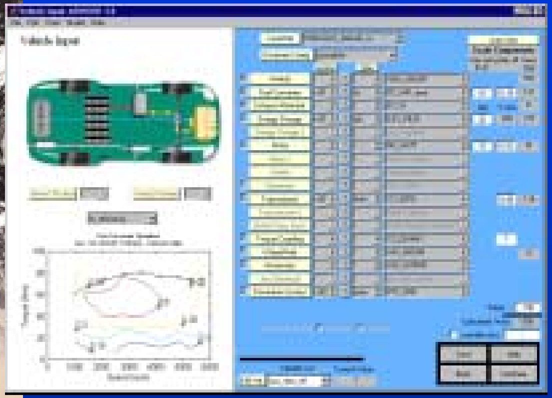



**Legend includes industry with 5 or more users**
**Total number of industries using ADVISOR = 577**

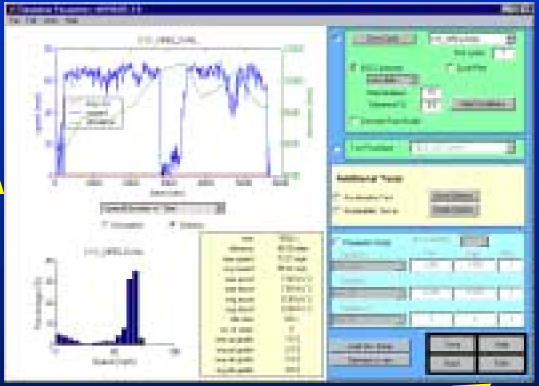
As of 8/17/00

# Three Main ADVISOR Screens (Roadmap)

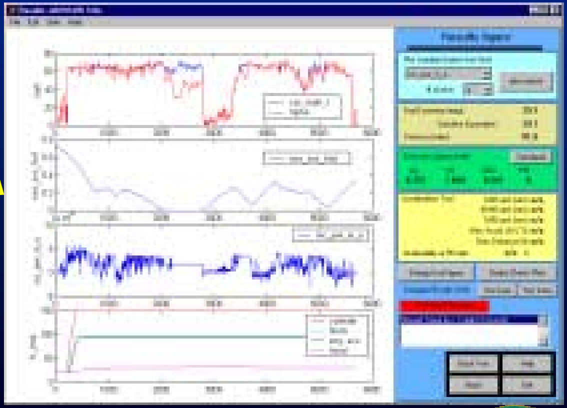
Vehicle Input



Simulation Setup

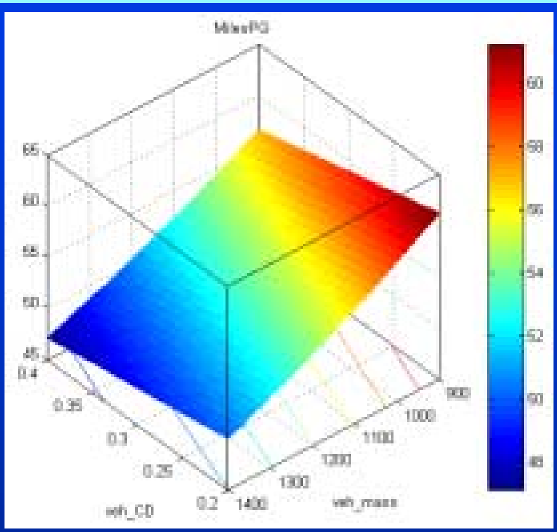


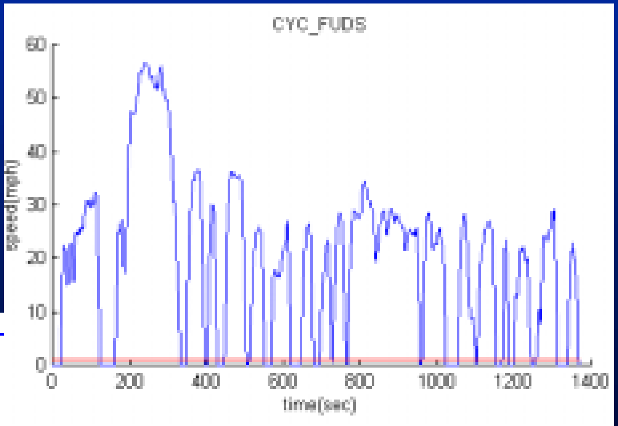
Results

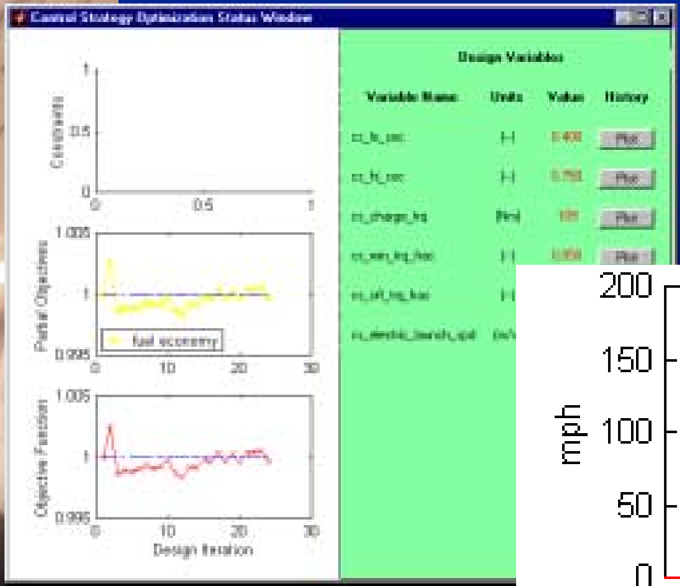


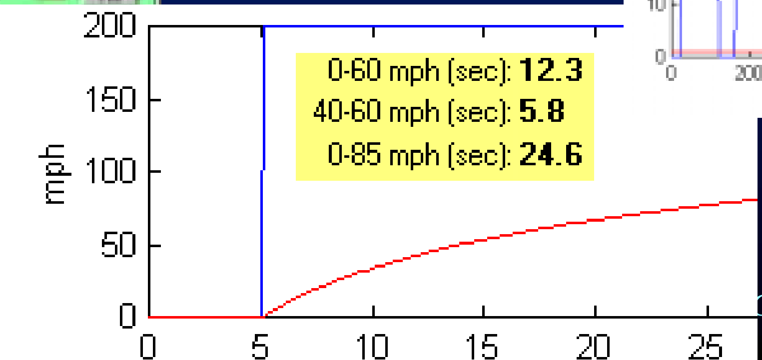
# Types of Simulation Tests Possible

- Parametric sweeps
- Drive cycles
- Acceleration and grade tests
- Control Strategy Optimizations



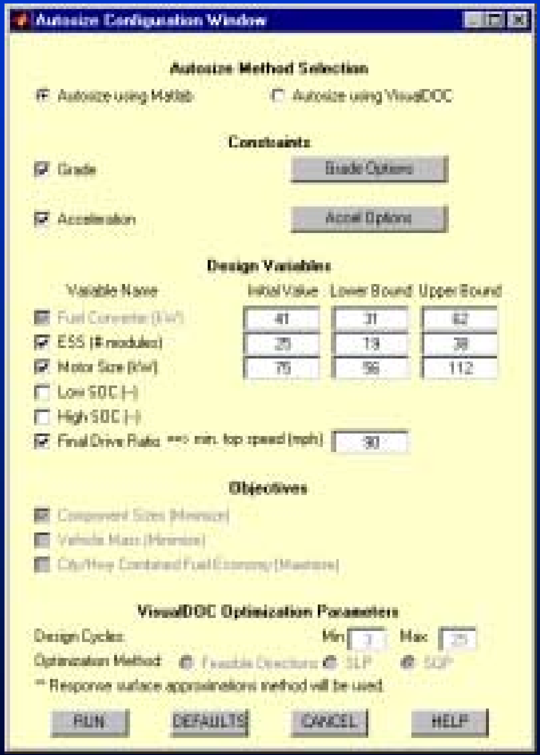



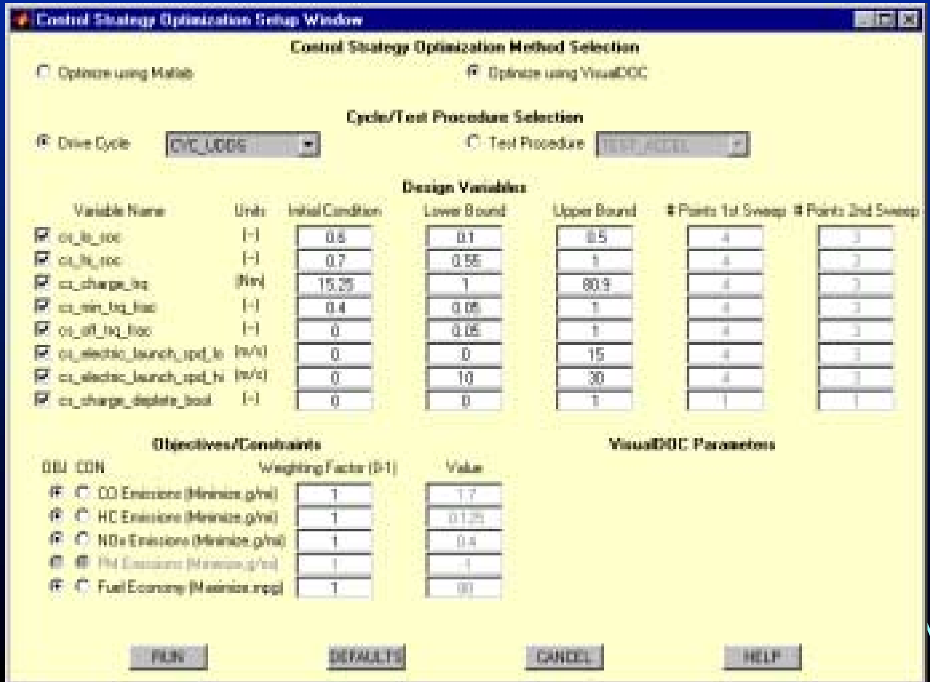
# Problem Definition

- Objective
  - Maximize fuel economy of fuel cell powered hybrid electric SUV
- Constraints
  - Performance equivalent to comparable conventional vehicle
    - 7 inequality constraints
- 8 Total Design Variables
  - 4 Component Characteristics
    - fuel cell peak power
    - traction motor peak power
    - number of battery modules
    - capacity of battery modules
  - 4 Control Strategy
    - low power fuel cell power cut-off
    - high power fuel cell power cut-off
    - minimum fuel cell off time
    - charge power set point

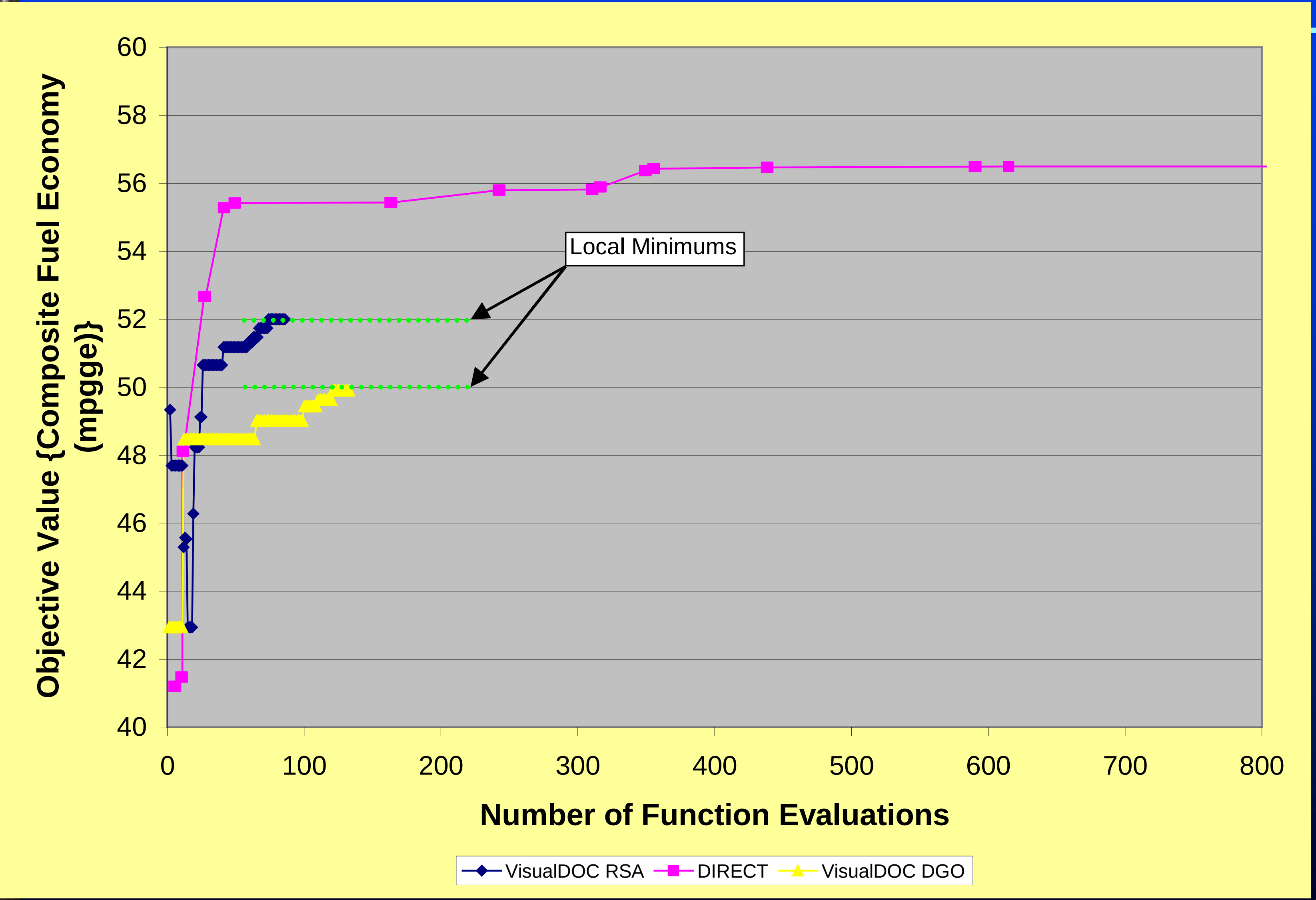
# Current Implementation

- 2 step process
  - adjust component characteristics
    - guess control parameter settings
  - adjust control parameters
- With optimization tools
  - all in one step!

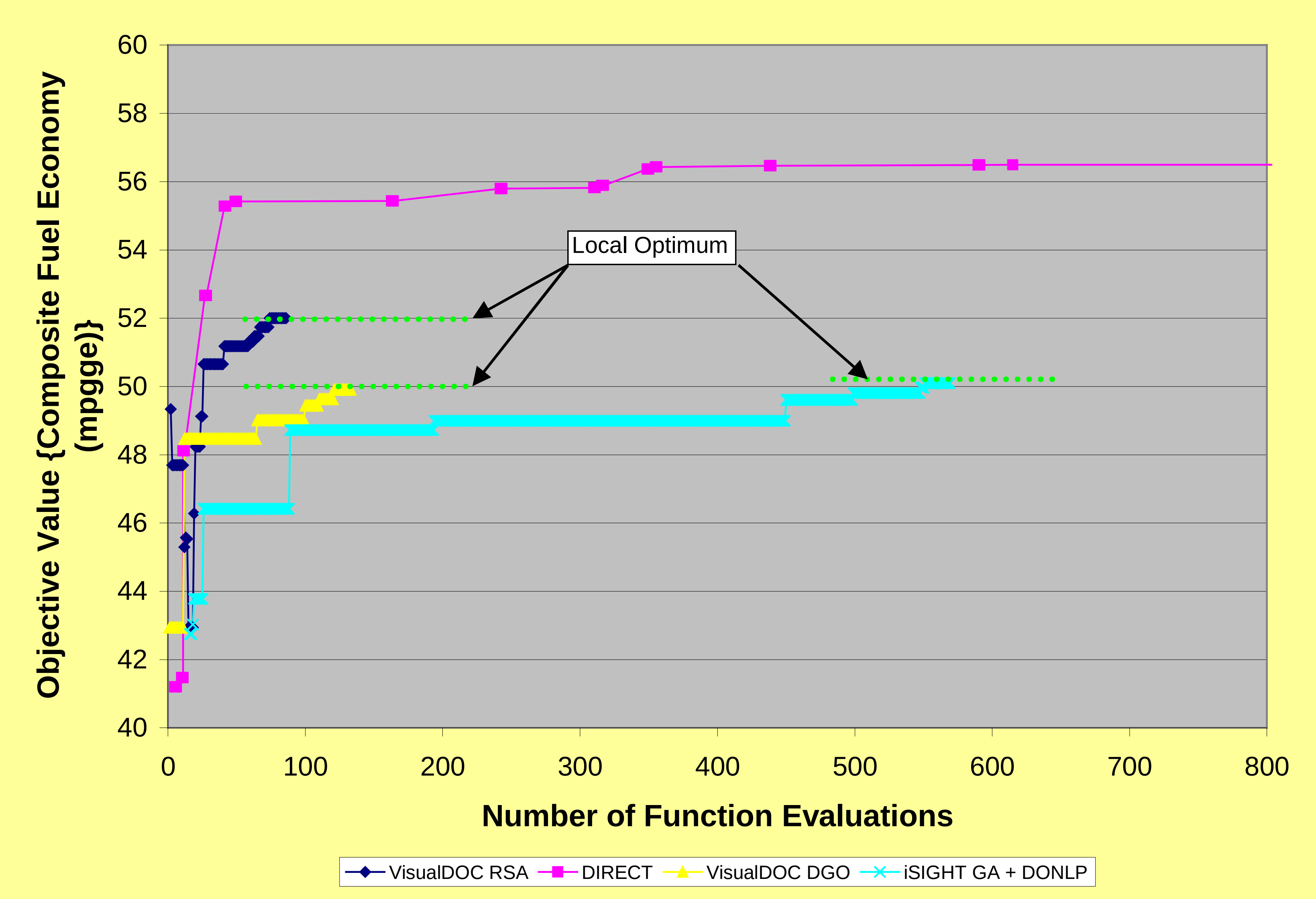


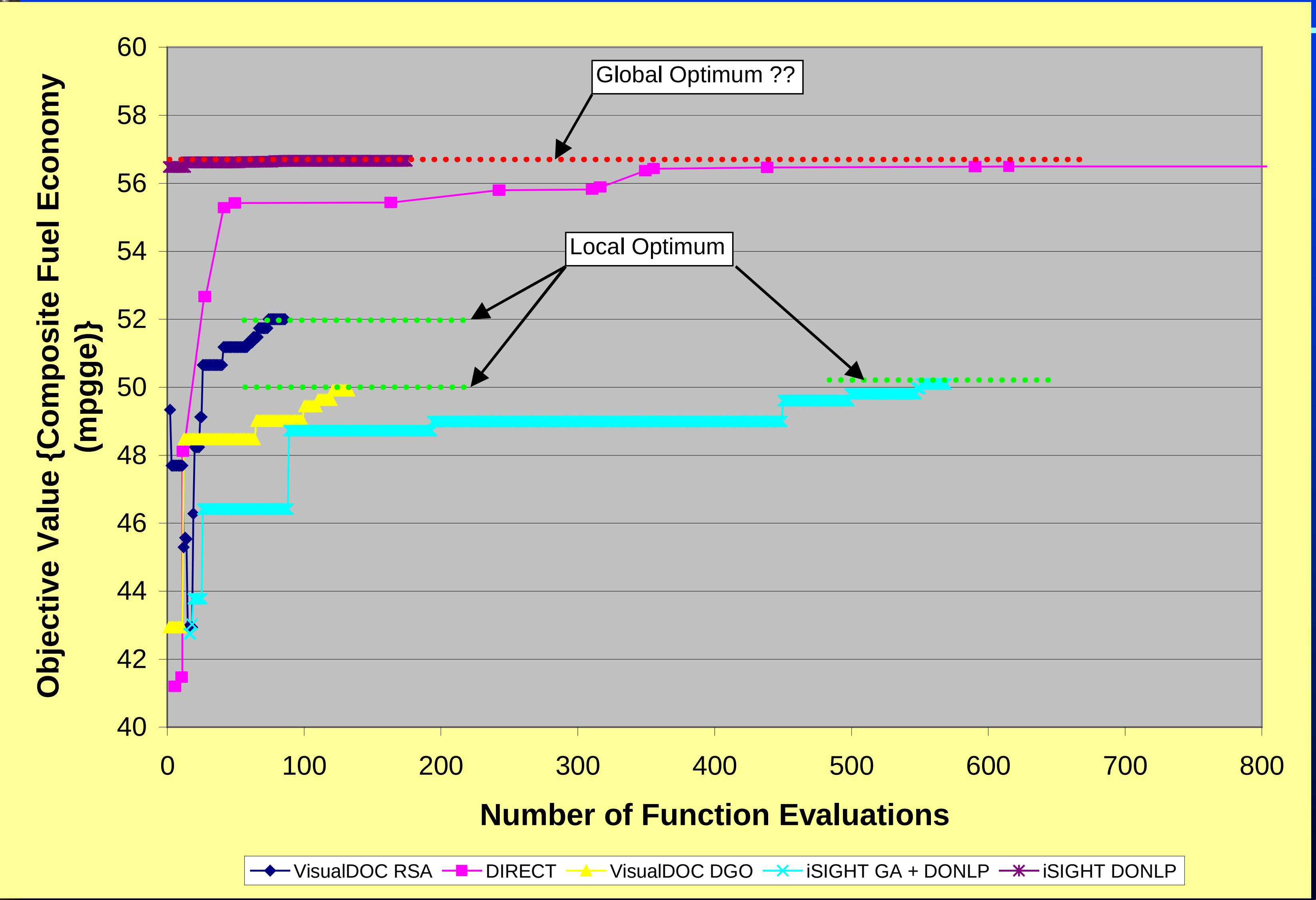
# Recent Application of Other Optimization Tools



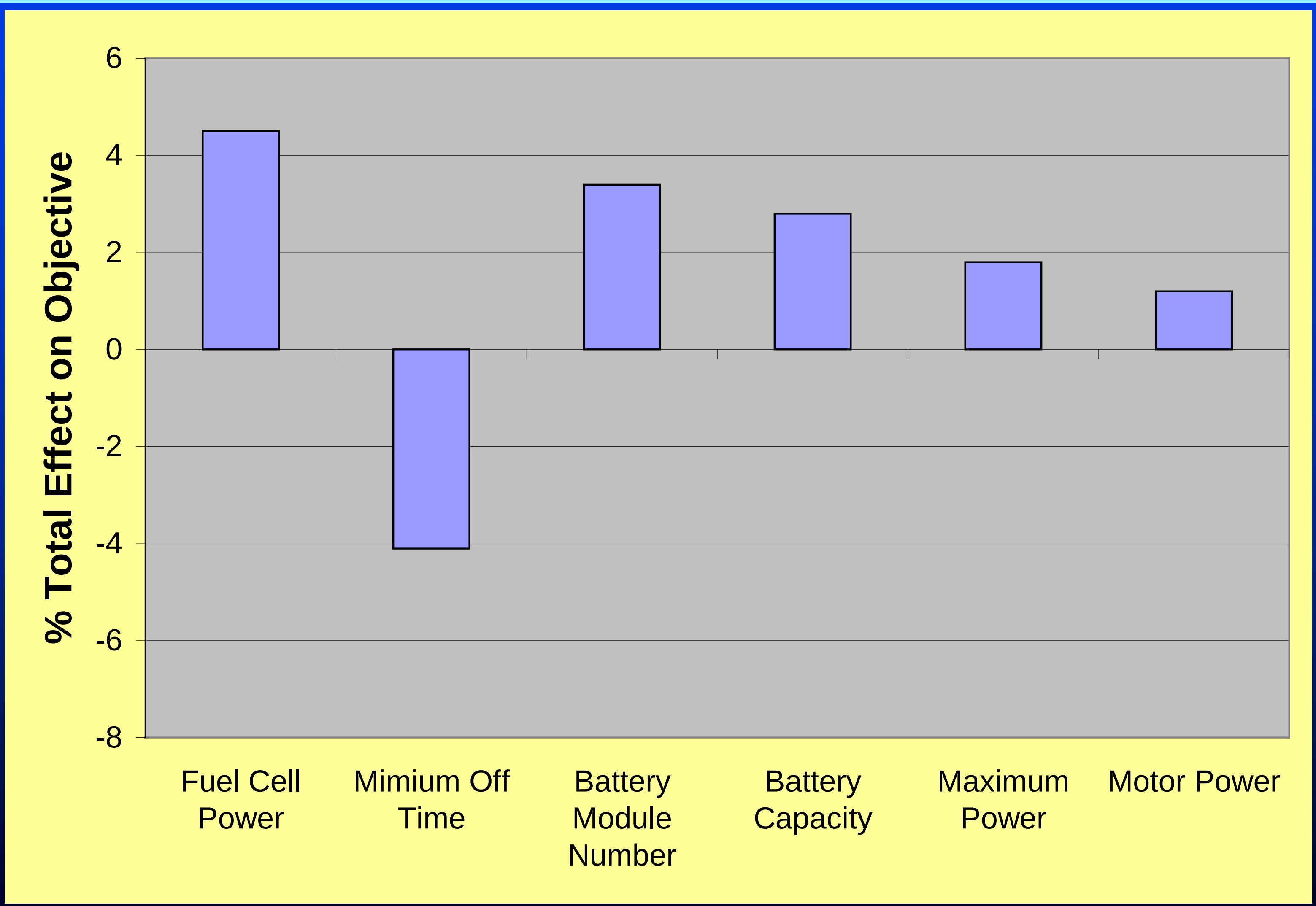
# iSIGHT Starting from initial conditions ...



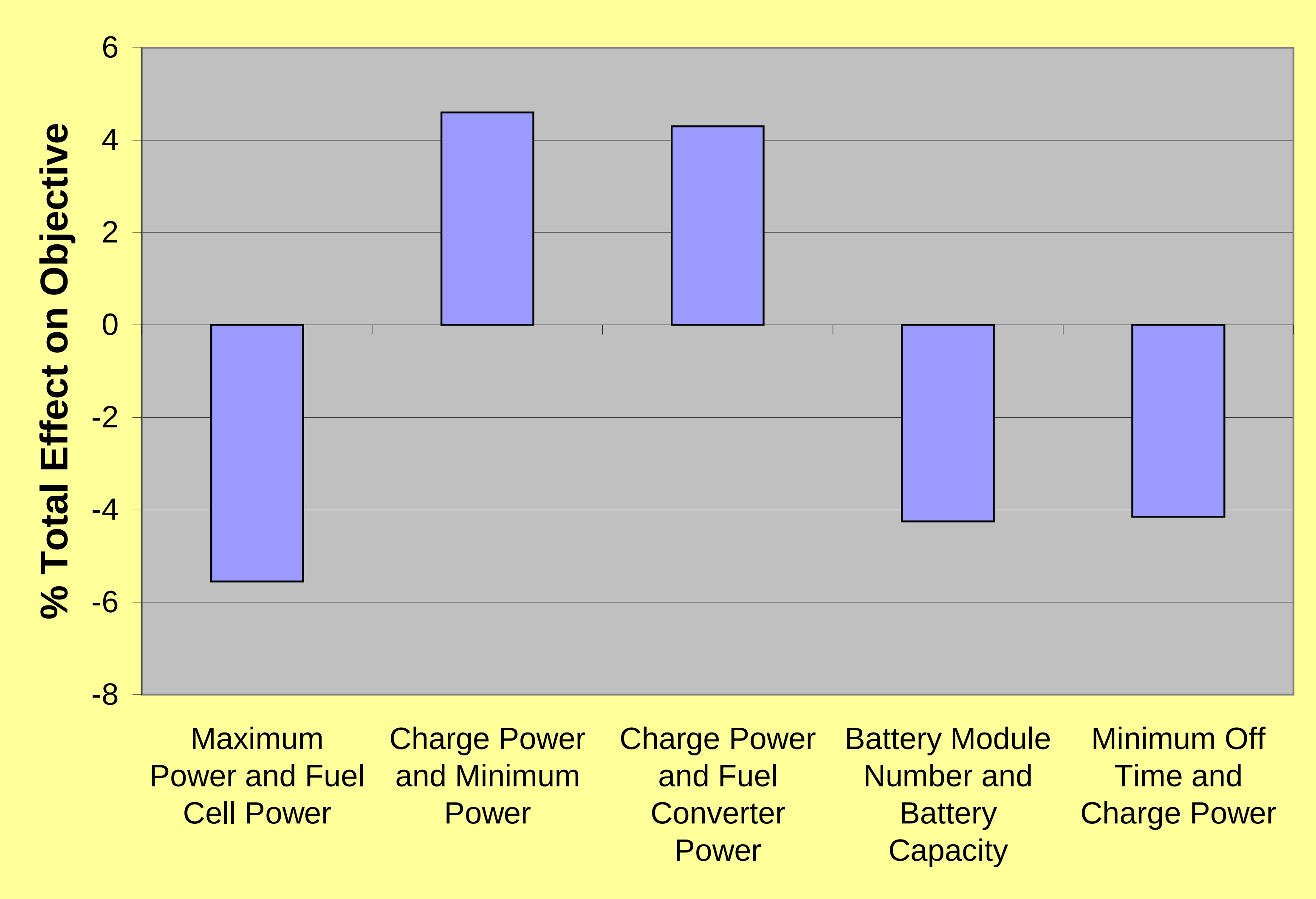
# iSIGHT Starting from best known conditions …



# DOE Results - Leading Individual Effects



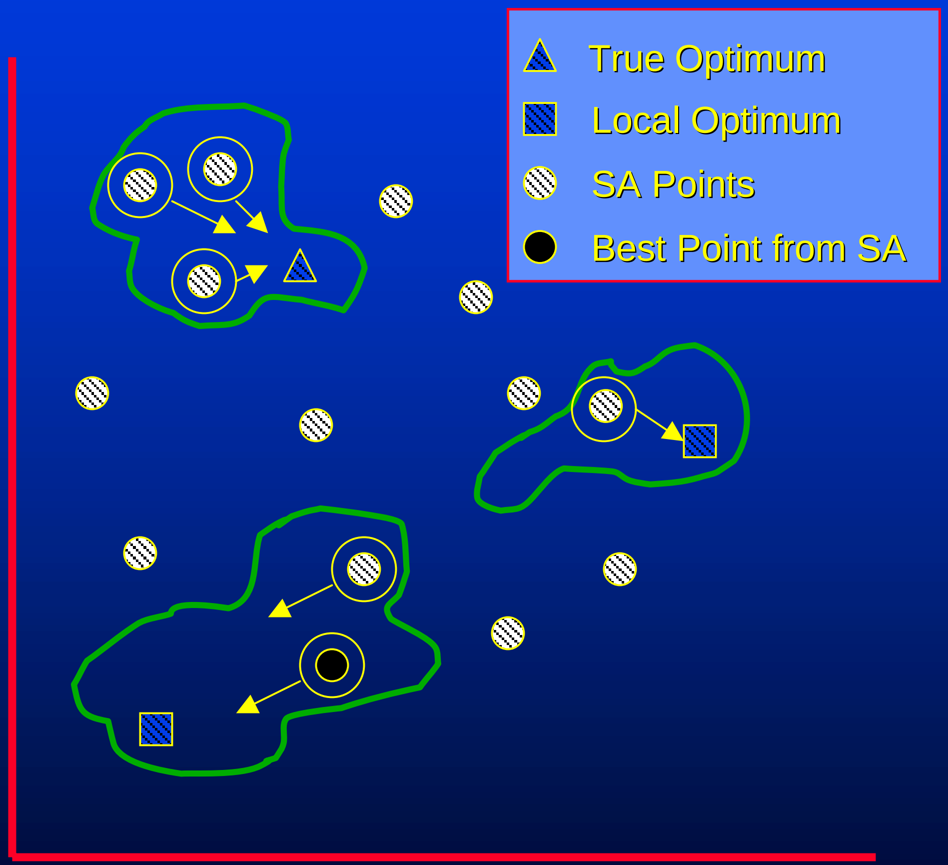
# Interactions more influential than individual effects!
# DOE Results - Leading Interactions



# Top Five Design Parameters Identified by DOE Using iSIGHT

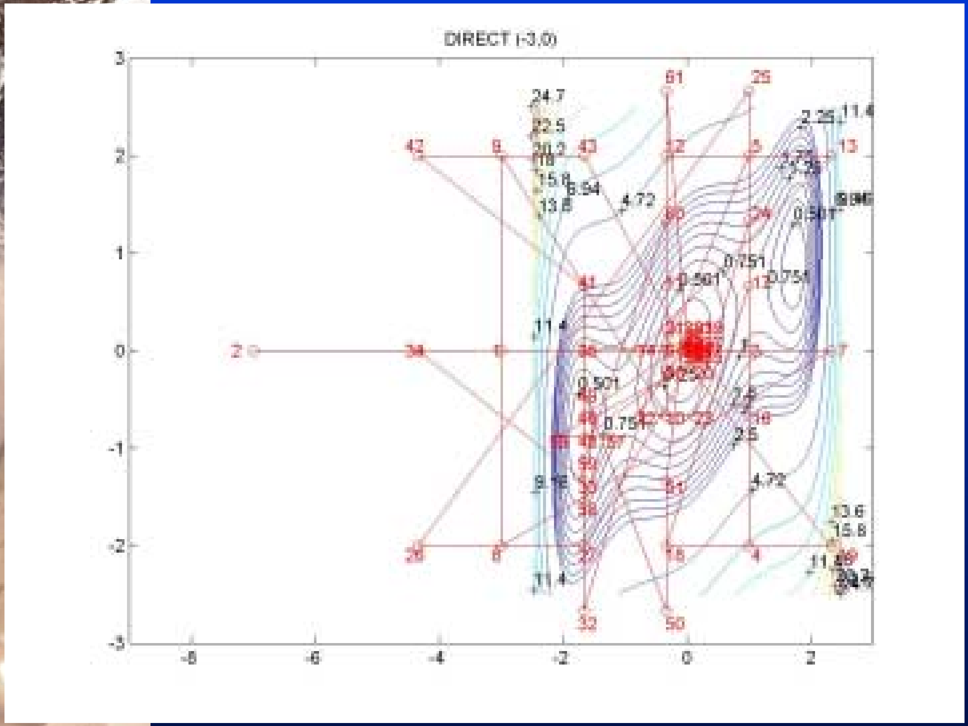
- Charge Power
- Maximum Power
- Fuel Converter Power
- Minimum Power
- Battery Capacity

# Multi-Algorithm Approach




- Efficient solution method
- Ability to automate in iSIGHT
- Increased likelihood of finding global optimum
- Especially Effective on noisy/discontinuous/ infeasible design spaces

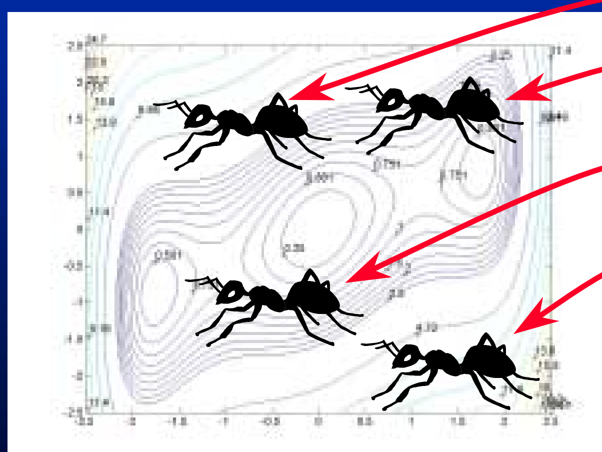
# DIRECT for Locating Local Optimum Regions

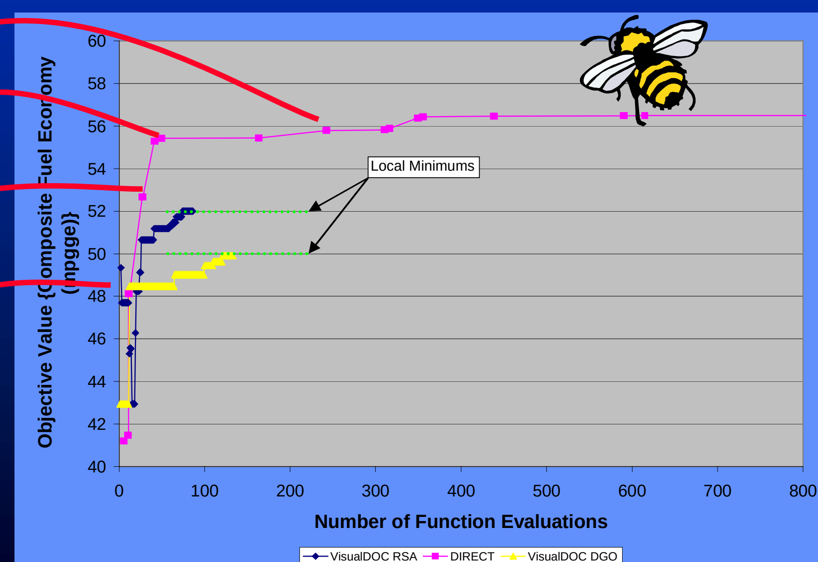



- DIRECT - is an algorithm that searches both locally and globally
- Restart functionality at any time
- Initially proposed by Donald R. Jones
- Limited to small number of design variables
- Great potential for parallelization

# Parallel Processing of Gradient and Non-Gradient Based Solutions

- Use non-gradient based algorithm (*the bee*) to generate start conditions
- Spawn new gradient based processes (*the ants*) at each change in design iteration
- Process both gradient and non-gradient solutions in parallel
- Choose best of multiple solutions



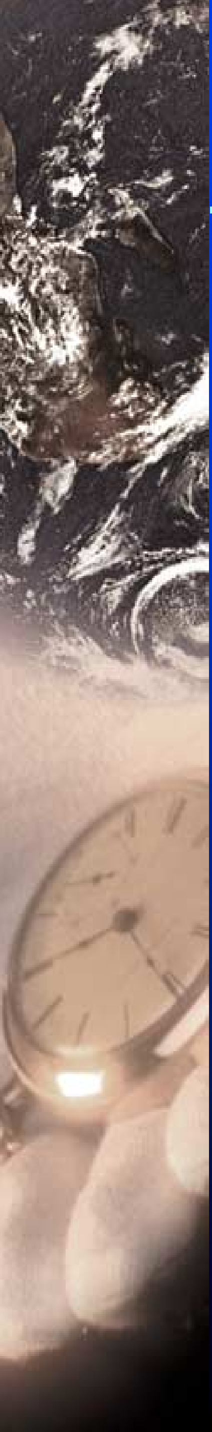


# Conclusions

- Identification of critical parameters of fuel cell powered hybrid electric SUV is very challenging
  - Large number of variables
  - Very little experimental data
  - Strong coupling between the parameters (factors)
  - Effect of most factors on fuel economy is non-monotonic
- Ignoring the coupling leads to faulty conclusions
- Combination of system analysis tools (ADVISOR) and modern optimization tools (iSIGHT) is key in hybrid vehicle design studies

# Future Plans

- Improved communication mechanism between iSIGHT and MATLAB
- Multi-objective design optimization with multi-disciplinary CAE (Digital Functional Vehicle)
- Distributed/parallel processing
- Experimental verification of assumptions, conclusions and results
- Identification of industry partner for collaboration and identification of additional objectives



# 2001 Joint ADVISOR/PSAT Vehicle Systems Modeling User Conference

## August 28-29, 2001

## @ USCAR Southfield, Michigan

Focus Areas

Optimization

Control Strategy

Hybrid Powertrain

Fuel Cells

Model Validation

www.nrel.gov/transportation/analysis/conference.html